CEMENT AND LIME MANUFACTURE

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New Cement Works in Sweden.

A ROTARY kiln 478 ft. in length has been installed at the works (*Figs.* 1 and 2) at Koping, Sweden, of the Skanska Cement Company. The new works started production in the year 1941, and is operated on the wet process.

Raw material and clinker are ground in open circuit through large multiple-compartment mills, and limestone is transported 28 miles by overhead cableway from the quarry to the mill. The works is designed for future installation of a second long kiln, and utilises limestone and clay excavated from the river adjacent to the works in the proportions of about 5 : 1. The limestone averages 92 per cent. $CaCO_3$ with a maximum of 98 per cent. Excavating is by electric shovels. A $\frac{7}{8}$-cu. yd. Bucyrus machine handles the stripping, and excavation is done by a $2\frac{1}{2}$-cu. yd. Rapier shovel and a $2\frac{1}{2}$-cu. yd. Menck shovel. Transport of stone from the far side of Hjalmar Sound would have required 70 lorries, so a cableway 28 miles in length was constructed (*Fig.* 3). It was erected in four sections with

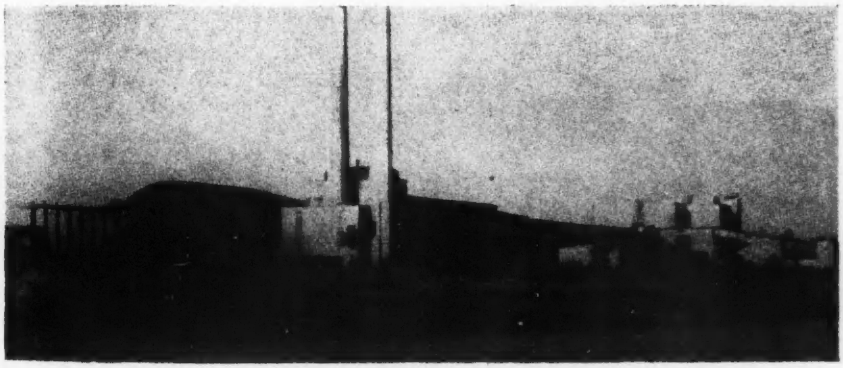

Fig. 1.—Cement Works at Koping, Sweden.

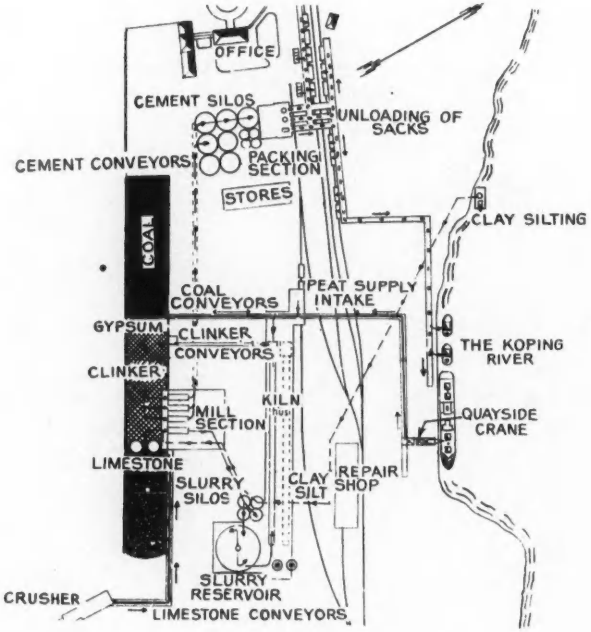

Fig. 2.—Plan.

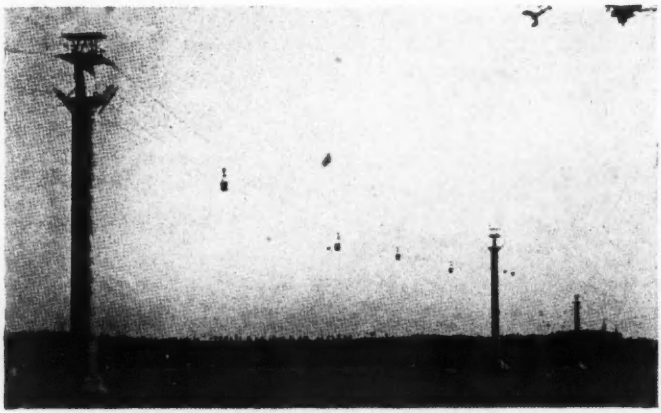

Fig. 3.—Cableway (28 miles long) for Transporting Limestone.

transfer stations between. The towers over open water are 148 ft. high and 1,770 ft. apart, since the waters traversed are open to navigation. Each bucket carries 1.2 metric tons of stone. Two of the sections have separate drives, while the other two have a double combination drive. The stone is passed through a 5½-ft. cone crusher to ¾-in. minus, followed by pulverisation to a maximum size of $\frac{1}{215}$ in.

The long axis of the plant, including a single storage building for all the bulk materials, is parallel with the river, and raw and finishing grinding are done in

Fig. 4.—Dredging Clay from River.

an adjoining building. Storage is provided for 44,000 tons of limestone, 44,000 tons of clinker, 5,500 tons of gypsum rock, and 38,000 tons of coal, with an overhead travelling crane for handling. Messrs. F. L. Smidth and Co., of Copenhagen, were the engineers and manufacturers of most of the machinery.

The clay is a silty material excavated from the river (*Fig.* 4) and is pumped into silos. After grinding, the clay slurry of 70 per cent. water content is pumped

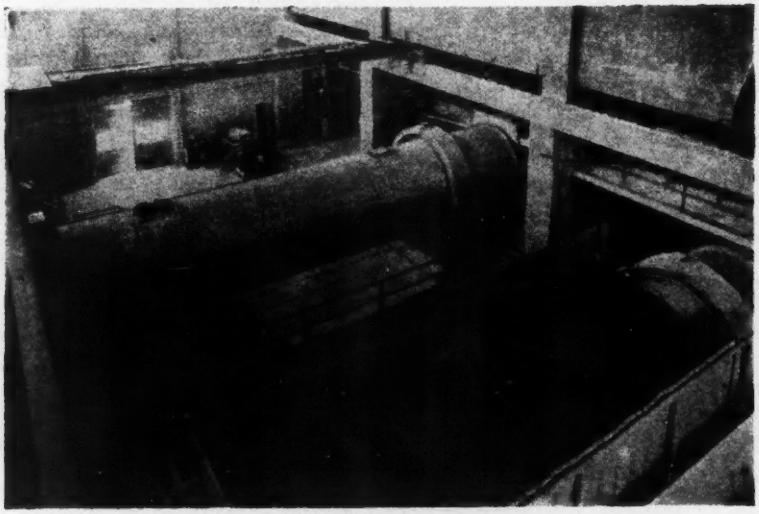

Fig. 5.—Raw Grinding Mill.

Fig. 6.—Rotary Kiln, 478 ft. long.

from the wash mill to the raw grinding mill (*Fig.* 5) for intergrinding with the limestone. Grinding is in open circuit in an 8½ ft. by 43 ft. 4-compartment mill to a fineness of approximately 250-mesh. The product is pumped into silos for analysis and correction, followed by storage in an air-activated thickener of 200,000 cu. ft. capacity, sufficient for a week's operation of the kiln. It is pumped to the kiln and fed, with 34 per cent. contained water, by a Ferris wheel feeder into the kiln.

The kiln (*Figs.* 6 and 7), a Unax with an integral cooler, is 478 ft. in length and 11 ft. 9½ in. in diameter, with a calcining zone restricted to 10 ft. 6 in. diameter. It is designed for direct-firing by coal from an air-swept ball mill, using preheated

Fig. 7.—Firing End of Kiln and Control Board.

air for the grinding process. Fuel economy was a major factor. Heat recuperation is effected through the Unax clinker cooler, and heat exchange chains are installed in the back end of the kiln. In addition, the kiln is equipped with a spiral slurry drier and a " cross " inside the kiln. The slurry drier is a chamber in the kiln a short distance from the inlet and divided into segments, thus separating the slurry into different compartments and exposing smaller quantities to the action of the gases. Loose coils in these compartments help to expose thin layers of the slurry to the gases. The "cross" is a heat exchange system which divides the clinker stream into smaller masses so as to expose more surface to the hot gases. At a rated capacity of 442 tons per day, clinker is manufactured with a heat utilisation of 1,250 calories per kilogramme, or approximately 141,670 B.Th.U. per ton. The kiln is fired at 2,700 deg. F. and the temperature of the

exhaust gases averages 275 deg. F. The temperature at the point where the material leaves the " cross " is 1,225 deg. F.

The clinker is ground in open circuit. It is transported into storage from the cooler by a manganese steel drag conveyor and withdrawn for grinding, with added gypsum, through three 7 ft. 11 in. by 39 ft. 6 in. 4-compartment mills in open circuit. As a war-time expedient, a synthetic gypsum, a by-product from copper smelting by the treatment of phosphate rock, was interground as a retarder with the clinker. The finished cement is pumped into silos. The storage capacity is 48,300 tons, in seven 47 ft. 6 in. diameter by 95 ft. reinforced concrete silos.

Throughout the war much of the production was E-cement, a product inferior to standard Portland cement which could be sold without licence. E-cement is a low-heat cement manufactured by intergrinding standard Portland cement with various other materials including slag from coke ovens, granulated water-cooled slag, sandstone, and even quarry refuse. It was sometimes called " sand cement," was easily ground, and gave concrete with a compressive strength of 3,500 lb. per square inch at 28 days. The cement is packed in paper bags by two Fluxo and one Bates automatic packing machines.

As it is necessary to restrict the use of coal, which is imported into Sweden a mixture of charcoal dust, peat and coal is used as fuel. Charcoal and peat are transported by rail, the peat being carried 28 miles from bogs owned and operated by the company. The peat is reclaimed by machine-cutting, drag conveyors, or by suction methods. It is shredded by toothed blades, dried, milled, and taken in powdered form to the works.

Cement Production in the United States.

IT is reported by the Bureau of Mines of the United States Department of the Interior that the quantity of cement produced in the United States in November, 1945, was 10,700,000 barrels. This is higher than the average production for the month of November for the years 1935 to 1939, and compares with a production of 8,304,000 barrels in November, 1944. The deliveries made from the works were 10,342,000 barrels in November, 1945, compared with 7,380,000 barrels in November, 1944.

Analysis of Test Results.

THE recent re-issue of British Standard No. 1008, " Guide for Quality Control and Control Chart Method of Analysing Data," retains the symbols common in American practice (upon which this standard is based). These symbols differ from those used in British practice, for example, in British Standard No. 600R, " Quality Control Charts." In the present description of the American method, conversion has been made to British symbols.

Quality control is applicable to the manufacture of materials or products the standard of which must be within specified limits, and particularly appertains to large production, continuous flow, or batches of considerable size. Briefly, the process of statistical quality control involves the systematic collection, arrangement, and analysis of test results with the object of detecting non-uniformity of quality of the material. A control chart is prepared, and this constitutes a graphical record of variations of quality. An upper and lower control limit is indicated thereon, and a sample falling outside these limits indicates the need for an investigation into the cause of the variation. The control limits are not necessarily the same as the specification limits as the former are not used, as are the latter, for directly checking the quality of the finish material, but as a basis for judging the significance of variations between samples. Thereby a criterion is established for detecting disturbances in a manufacturing process. Such disturbances, the time and place of which the control chart can establish, may be assigned to variations in raw materials or in workmanship, or to irregular performance of the manufacturing plant, or even of test apparatus. A manufacturing process is said to be in a state of statistical control when all test results lie within the limits on the control chart, and when this condition is reached no greater uniformity is possible with the particular process examined. If, in spite of a condition of statistical control having been attained, the material fails to conform to the specification, it is an indication that the manufacturing process requires basic alteration or that the specified limits are too severe having regard to the materials and practical methods of manufacture.

The advantages of attaining a condition of statistical control are self-evident, provided that the specified limits are not too wide. In particular such a condition enhances the reliability of sample testing and induces confidence when considering the results of sample testing as indicative of the quality of the bulk material.

The control limits are calculated from data derived from test records and formulæ of proved reliability. It is not possible to lay down hard-and-fast rules for setting these limits, but general recommendations have been authoritatively made. The control limits are essentially above and below the grand average of the numerical value of the statistical measure of the samples being examined.

Statistical Measures.

The statistical measure of a group of n samples may be either (i) the average $\bar{x}$ for the samples, which is the sum of the observed results for n samples divided

by n; (ii) the standard deviation s, which is the root-mean-square deviation of the observed results from their average value; or (iii) if n is not greater than 10, the range w in place of s, the range being the difference between the largest and smallest observed results in a group. A further statistical measure, the fraction defective (m), is merely the number of samples which fail to comply with the specification or other requirement.

Thus, if the observed results of n samples arranged in ascending order of magnitude are $x_1, x_2, \ldots x_n$, $\bar{x} = \frac{\Sigma_1^n x}{n}$, $s = \sqrt{\frac{\Sigma_1^n (x - \bar{x})^2}{n}}$, and $w = x_n - x_1$.

If the number of samples is very great, the arithmetical work involved in solving these expressions is likewise great, and in B.S. 600R (1942) some rules are given for reducing the amount of arithmetical work.

Control Limits.

The distances of the control limits above or below the grand average of the selected statistical measure are, in accordance with American practice, three times a computed value termed "sigma," and are referred to as "3-sigma" limits. Thus normally the control limits are equidistance about the grand average, except when the computed lower limit for w or s is negative, in which case the lower control limit is placed at zero.

The standard values of $\bar{x}$, s and m, that is the values laid down in the specification, are denoted by $\overline{X}$, σ and $\overline{m}$. The control limits used in British and American practice differ slightly in magnitude. Whereas, as described in the foregoing, the limits in American practice are based on the whole of the observed results, in British practice a specific proportion (1 in 1,000) above or below the upper and lower limits respectively, is excluded. In the construction of control charts and the plotting of the centre line and control limit lines thereon, there are two distinct procedures depending on whether or not a standard value for a given property of the material is specified.

Control Charts with Specified Standards.

The object of the control chart in this case is to determine whether the value of $\bar{x}$, s, etc., for k groups of n samples each varies from the specified values $\overline{X}$, σ, etc., by an amount in excess of that attributable to chance. The observed results of the samples should be divided into groups containing equal numbers of observations, each group having a common factor such as time, or a particular stage in the process of manufacture. The total number of observations is thus divided into k groups of n observations each. (If the number of observations in each group is not constant, the formulæ given later require modification as explained in the appropriate British Standards; it is obviously advantageous to make n constant in routine testing.) For each statistical measurement, such as $\bar{x}$, s, etc., a control chart is constructed.

The chart consists of a central line and upper and lower control limit. The central line, in the case of specified standards being given, is drawn at the following

levels: (i) for averages, at $\overline{X}$; (ii) for standard deviations, at $b_n\sigma$; and (iii) for ranges, at $d_n\ \sigma$. The values of b_n and d_n (to three significant figures) are:

n	2	3	5	10	15	20	25	>25
b_n	0·564	0·724	0·841	0·923	0·949	0·962	0·970	1·00
d_n	1·13	1·69	2·33	3·08	3·41	—	—	—

The control limit lines are drawn at the following levels: (i) for averages, at $\overline{X} \pm \frac{3\sigma}{\sqrt{n}}$; (ii) for standard deviations, at $b_n\sigma \pm \frac{3\sigma}{\sqrt{2n}}$; and (iii) for ranges, at $D_{0{\cdot}001}\sigma$ and $D_{0{\cdot}999}\sigma$, where the values of D (to three significant figures) are:

n	2	3	7	8	9	10	12	15
$D_{0{\cdot}001}$	(For $n <$ 7 = 0)		0·205	0·387	0·546	0·687	0·925	1·21
$D_{0{\cdot}999}$	3·69	4·36	5·20	5·31	5·39	5·50	5·59	5·74

Although the British symbols $D_{0{\cdot}001}$ and $D_{0{\cdot}999}$ have been used in the foregoing the tabulated numerical values of these factors do not correspond with the appropriate British values owing to the slightly different conceptions of the outer control limits adopted in British and American practice.

Since the calculations are more simple, the control chart for ranges is sometimes adopted in place of that for standard deviation, especially in routine tests. This substitution is not usually recommended for groups containing more than ten observations.

Control Charts with no Specified Standards.

In this case, the central and limit lines must be established from the observed results, and the following rules apply if each of the k groups contains the same number n of samples, n being not greater than 25. In this case $\overline{X}$ denotes the grand average of the observed values for all groups. The central line of the control chart is (i) for averages, at $\overline{X}$; (ii) for standard deviations, at $\bar{s} = \frac{\Sigma_1^k s}{k}$; and (iii) for ranges when $n = \not> 10$, at $\overline{w} = \frac{\Sigma_1^k w.}{k}$ The control limit lines are (i) for averages, at $\overline{X} \pm \frac{3\bar{s}}{b_n\sqrt{n}}$; (ii) for standard deviations, at $\bar{s} \pm \frac{3\bar{s}}{b_n\sqrt{2n}}$; and (iii) for ranges when $n \not> 10$, at $D'_{0{\cdot}001}\,\overline{w}$ and $D'_{0{\cdot}999}\,\overline{w}$, where b_n has the values tabulated above, and D' (subject to the previous comments relating to D) has the following values to three significant figures.

n	2	3	7	8	9	10
$D'_{0{\cdot}001}$	(For $n <$ 7, = 0)		0·076	0·136	0·184	0·223
$D'_{0{\cdot}999}$	3·27	2·57	1·92	1·86	1·82	1·78

Use of Control Charts.

Many examples of the use of control charts in industrial processes are given in B.S. Nos. 600R (1942) and 1008 (1942). From these there is little difficulty in selecting a procedure applicable to the various stages of manufacture in the cement and similar industries. This method of statistical control is, however, not limited in usefulness to the processes at the cement works, but can be used by engineers on the site of constructional works where large quantities of cement and other materials subject to deterioration during handling and storage are used.

Developments in Russia.

THE following notes relate to various types of cement produced in the U.S.S.R.

TETS cement, according to an article by Mr. A. M. Shchepetov in " Tsement," Vol. 10, 1944, is manufactured from limestone and coal-ash. The composition includes 14·3 per cent. of ferric oxide, 28 per cent. of lime, and 5 per cent. of sulphur trioxide. About 90 per cent. passes the equivalent of a B.S. No. 170 sieve. The compressive strength of 3 : 1 mortar at 28 days is 1000 lb. per square inch. Initial and final setting times are 2 hours 20 minutes and 8½ hours respectively. Steam-cured concrete products containing between 500 lb. and 840 lb. of this cement per cubic yard are said to be very satisfactory.

In the same volume of " Tsement," Mr. A. V. Stepanov describes a lime-slag cement that has been produced at Magnitogorsk since 1943. The constituents from which it is manufactured are 80 to 85 per cent. of granulated slag, 15 to 20 per cent. of quicklime, and 3 to 5 per cent. of crude gypsum.

A cement made from a dolomite found in Russia is described by Messrs. V. M. Permajakov and V. E. Shuravlev in the Russian " Journal of Applied Chemistry," 1943, Vol. 16. The dolomite is heated to a temperature of 800 deg. C., finely ground and mixed with sand.

Messrs. P. P. Budnikov and V. M. Leschoev discuss, in " Comptes-Rendus Academie des Sciences de l'U.S.S.R.," Vol. 45, 1944, a theory of the solidification of sulphated slag cement. A feature of this cement is that the large proportion of calcium sulphoaluminate formed during setting does not produce swelling. The initial strength increases with the separation of calcium hydrosilicates and hydroaluminates derived from the sulphoaluminates. The progress of the setting process is determined by the concentrations of free lime and calcium sulphate in the solution. The free lime concentration should be between 0·4 and 1·08 grammes per litre, and this degree is attained by adding 3 per cent. of lime (or 7 per cent. of Portland cement) to the gypsum-slag mixture.

A straight-line inverse relationship exists between the gehlenite content in aluminosilicate cement and the mortar strength. This rule is established by Messrs. N. A. Toropov and V. V. Serov in " Journal of Applied Chemistry " (Moscow), Vol. 17, 1944. Aluminosilicate cement is chemically placed between Portland cement and high-alumina cement.

New Apparatus for Accelerated Freezing and Thawing Tests.

IN view of the many unavoidable differences between the effects of exposure to the atmosphere and any of the accelerated tests now used in an attempt to forecast the effects on concrete of freezing and thawing, the Corps of Engineers of the United States Army came to the conclusion that the most suitable test was one that was limited in procedure, which was easily reproducible, and which was rapid enough to permit an estimate of the potential relative durability of concrete to be made in a reasonable time. A new apparatus was therefore devised, and this is described in the Second Interim Concrete Research Report of the Central Concrete Laboratory of the U.S. Army, Mount Vernon, New York, from which the following is taken.

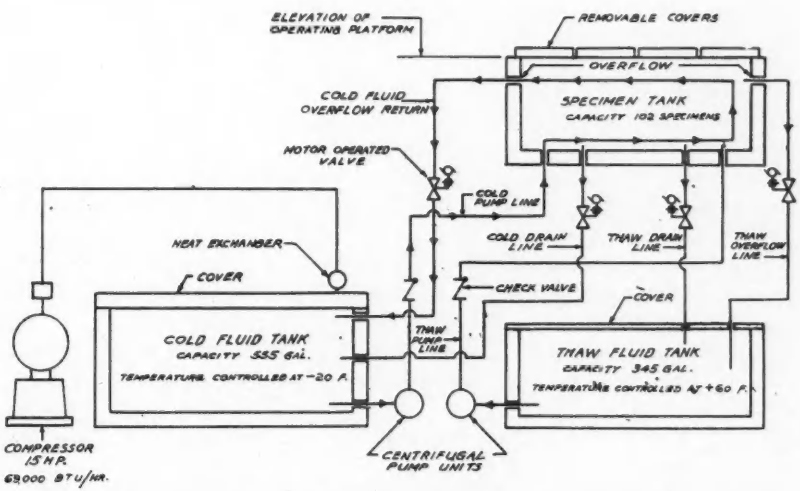

Fig. 1.—Arrangement of Automatic Freezing and Thawing Apparatus.

It was believed that a procedure should be devised in which all of the conditions would be constant and the results available within 28 days. It was decided to devise an apparatus which would: (*a*) be entirely automatic and require no movement of the specimens during reversals of temperature, (*b*) develop thermal gradients of a severe but highly reproducible nature, and (*c*) maintain a constant moisture saturation. The premises upon which the mechanical design was based were: (*a*) reduction in temperature from 42 deg. F. to 0 deg. F. in one hour, (*b*) elevation of temperature from 0 deg. F. to 42 deg. F. in the second hour, (*c*) reversals of this cycle to the number desired, (*d*) immersion of the specimen at all times in water, and (*e*) uniform thermal effect on all specimens tested.

The specimen decided on measures 3½ in. by 4½ in. by 16 in. ; such a specimen lends itself well to determination of dynamic modulus of elasticity by vibro-electronic means, permits the use of coarse aggregate of 1 in. or 1¼ in. maximum size and allows a large number of specimens to be tested in a given space.

Description of Apparatus.

The major apparatus consists essentially of three insulated tanks, one for the cold fluid, one for the thawing fluid, and one for the specimens, with means for refrigerating the cold fluid and heating the thawing fluid, and the necessary pumps, valves, and controls to circulate the solutions through the specimen tank at the required temperatures, time intervals, and rates of flow. The arrangement of the apparatus is shown in *Fig.* 1.

FREEZING AND THAWING SOLUTIONS.—A solution containing 60 per cent. specially denatured alcohol* and 40 per cent. water is used for both the cold and thawing fluids. The use of alcohol permitted construction of the apparatus with less expensive materials than would have been required for more corrosive brine solutions. Solutions for freezing and thawing are used at the same concentrations because of the impossibility of preventing some intermixing in the specimen tank. The solution has a freezing point of approximately 40 deg. F. While the average temperature of the cold fluid is –20 deg. F. the refrigeration-plate temperatures are as low as –35 deg. F. and require a solution that will not freeze at less than –40 deg. F. Approximately 540 gal. of alcohol and 360 gal. of water were required to charge the system.

COLD TANK AND REFRIGERATION EQUIPMENT.—The cold tank is lined with 16-gauge galvanised iron with welded joints and is insulated with 8 in. of cork-board covered with 20-gauge galvanised iron. The inside dimensions of the tank are 21 in. deep, 60 in. wide, and 126 in. long, and it contains twenty-five 12-in. by 103-in. refrigeration plates having double radiation surfaces. The plates are assembled in units of five, each unit being controlled by a separate multiport thermostatic expansion valve. This method of assembly and operation will maintain the required temperatures if one unit is not functioning because of a frozen expansion valve. An insulated chamber on the top of one end of the tank contains the expansion valves, refrigerant piping, solenoid valve, and thermostat. The refrigeration is performed by a 15-h.p., 220-v., 60-cycle, 3-phase, water-cooled condensing unit, using Freon F-12 as the refrigerant, and has a capacity of 69,000 B.T.U. per hour. The capacity of the cold tank with plates installed and when filled to within 2 in. of the top is approximately 550 gal. The solution is removed from the bottom of the tank through a 2½-in. pump line and is returned at the top of the opposite end of the tank through a 3-in. gravity flow line from the specimen tank. This method of inlet and discharge provides ample circulation across the refrigeration plates and mechanical agitation is not necessary.

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* Five gallons of methyl alcohol to 100 gal. ethyl alcohol (95·17 per cent. ethyl alcohol by volume).

THAWING TANK AND HEATING EQUIPMENT.—The thawing tank is also constructed of 16-gauge galvanised iron, with 4 in. of rock wool insulation held in place with tongue-and-groove fir sheeting. The inside dimensions of the tank are 26 in. deep, 35 in. wide, and 108 in. long. Twelve 1,000-w., 220-v., immersion heaters are installed across the width of the tank 4 in. from the bottom and 8 in. apart. The heaters are controlled by a thermostat set at 60 deg. F. which actuates a 40-amp., 220-v., 3-phase magnetic contactor which operates the heaters. The solution in the thawing tank is maintained at a depth of 21 in. when not in circulation and at that depth the capacity of the tank is approximately 345 gal. The arrangement and size of the circulation lines are the same as for the cold tank.

SPECIMEN TANK, RACKS AND CONTAINERS.—The specimen tank is constructed of 12-gauge galvanised iron with welded joints and is insulated with 8 in. of corkboard covered with tongued-and-grooved fir sheeting. The inside dimensions with covers in place are 24 in. deep, 34 in. wide and 108 in. long. Four removable covers containing 8 in. of corkboard provide access to the tank. The covers are of the refrigerator-door type, and the edges are supported by steel channels covered with ¼-in. plastic material running across the width of and flush with the top of the tank. The plastic prevents freezing of the covers to the top of the tank. The tank also has a ¼-in. plastic frost-breaker running entirely around it at a point just below the elevation of the bottoms of the covers when they are in place, to prevent the formation of frost between the walls of the tank and the covers. There are two 3-in. drains in the bottom of the tank, centred and at the one-third points of the length. Two 3-in. overflow outlets are provided in one wall 17½ in. from the bottom and also at the one-third points of the length, which give a depth of solution of 19 in. when the solution is in circulation. The solution is pumped into the tank through a 2½-in. header pipe running along the bottom of the tank on the same side as the overflow outlets. The header pipe has three openings equally spaced along the length of the tank, the openings being 1 in., 1½ in., and 2 in. respectively to equalise their rate of discharge. The openings are directed slightly downward from the horizontal to cause a circular flow of solution across the lower portion of the tank and specimens, up to the opposite side, and back across the top portion to the overflow outlets.

The specimens are placed vertically in separate 24-gauge galvanised iron containers with covers, the inside dimensions of the containers being 3¾ in. by 4¾ in. by 21 in. deep. Four racks constructed of steel angle, strap and rod, to form an open structure through which solution can circulate freely, are used to hold the containers. The dimensions of the racks are such that they will fit through any of the four openings in the tank. Each rack holds 24 containers, the containers being kept equally spaced from one another by a grille at the top and another several inches from the bottom of each rack. The rack also keeps the containers 1 in. from the bottom of the tank. The four racks will accommodate 96 specimens, but since one of the openings was purposely made larger than the

others to accommodate odd sizes of specimens, there is room for six more specimens in this section making the total capacity 102 specimens.

The top of the tank is flush with the floor of the laboratory. The racks are lowered into the tank by means of a ½-ton electric hoist suspended from a monorail trolley.

PUMPS, VALVES AND CONTROLS.—Circulation of the cold and thawing fluids is accomplished by two centrifugal pumps rated at 80 gal. per minute at a 15-ft. head. The pumps are belt-driven by 1-h.p., 220-v., 3-phase, explosion-proof motors. Belt-driven motors were required because of the necessity of insulating the pumps with cork to prevent frost formation, which could not be satisfactorily accomplished with direct-connected motor pump units. Since only one solution is circulated at a time both pumps discharge into a common 2½-in. pipe leading to the distribution header inside the specimen tank. Leakage of solution from one pump line to the other is prevented by a check valve and a power-operated valve installed ahead of each pump. Common pipes are also employed in the overflow and drain lines from the specimen tank, the solution being directed to the proper return tank by valving through four electrically-operated globe valves, one valve each for the cold and thawing fluid drain lines, and one each for the cold and thawing fluid overflow lines. Since the specimen tank is at a higher elevation (approximately 4 ft.) than the cold and thawing tanks, overflow and drainage from the specimen tank are accomplished by gravity flow through 3-in. galvanised-iron pipes. All pipe lines are covered with brine-thickness cork pipe-covering.

Since all valves and pumps are electrically operated, circulation of the solutions is made entirely automatic by means of a 2-hour seven-circuit timer and a Veeder-Root predetermining counter. The timer consists of a series of cams mounted on a common shaft driven by a 2-hour electric clock motor. As the shaft revolves the cams open and close the circuits in their proper sequence. The clock motor is wired in series with the counter, which can be set at any desired number of cycles and opens the clock circuit and thereby stops all operation of the freezing and thawing apparatus when the desired number of cycles has been reached.

LIQUID-LEVEL SAFETY CONTROLS.—Without automatic liquid-level control devices it is possible for any of the three tanks to be filled to overflowing because of failure of any of the electric valves to operate or because of a transfer of the solution between the cold and thawing fluid tanks. Any difference in the level of the cold and thaw drain-valves or the cold and thaw overflow valves will also cause a cumulative transfer between the cold and thawing fluid tanks, the transfer being in the direction of the lowest valve. Overflow and loss of alcohol solution by either of the above means are prevented by a liquid-level control probe installed in each tank at a point 1 in. below the point where overflow might occur. If the solution touches any of the probes an electric circuit will be completed which after amplification through a vacuum tube operates a relay, closing all valves and stopping the pumps and maintaining the solutions at whatever level they may be.

TEMPERATURE RECORDS.—The temperatures of the cold and thawing fluids and of the circulating fluid in the specimen tank are recorded on the chart of a three-pen seven-day recording thermometer. The temperatures of the concrete specimens are recorded on a recording potentiometer by means of a thermocouple embedded in the centre of a concrete specimen installed in the specimen tank.

Operation of Apparatus and Results.

Apart from routine checking of liquid levels, solution concentrations, and general mechanical operation, the apparatus requires no attention other than setting the counter to the number of cycles desired. The apparatus requires no handling of specimens except when actual testing is required and provides a means of rapidly obtaining a large number of highly-uniform exposure cycles without attention.

The normal procedure is to store the specimens in moist air at 70 deg. F. for nine days after they are made, before subjecting them to test. It is also customary to have control specimens for each group of test specimens. The dynamic moduli of elasticity (E) of the test and control specimens are determined by vibro-electronic methods nine days after they are made.

The specimens are normally removed from the apparatus and their dynamic moduli again determined at 3 cycles, 10 cycles, and thereafter at intervals not exceeding 27 cycles. All results are expressed in terms of relative E which is the percentage change in dynamic E; the dynamic E at 0 cycles (nine-day age) being taken as 100 per cent. Freezing and thawing cycles are continued until the relative E has decreased to 50 per cent. of that at nine days, or until the test has been continued for the number of cycles desired. When the freezing and thawing exposure has been completed and the final determination of dynamic E has been made, the specimens are tested in flexure in a damp condition, using mid-point loading. The dynamic E and flexural strength of the control specimens are determined at 28 days. The durability factor (DFE) based on dynamic modulus of elasticity, and the durability factor (DFM) based on the modulus of rupture, are calculated from the following formula.

$$DFE = \frac{PN}{M}$$

where DFE = the durability factor as a percentage of the dynamic modulus of elasticity at 0 cycles, P = relative dynamic modulus of elasticity of 50 per cent. or greater, N = number of cycles at which P reaches 50 per cent., or the ultimate number of cycles of the test if P does not reach 50 per cent. prior to the ultimate cycle, and M = ultimate number of cycles of the test;

and from $DFM = \frac{M_2}{M_1} \times 100$

where DFM = durability factor as a percentage of the modulus of rupture of

stored specimens, M_2 = modulus of rupture of the frozen and thawed specimens in lb. per square inch, and M_1 = modulus of rupture of the stored control specimens in lb. per square inch.

The apparatus described was completed in February, 1945, and a similar, but smaller, apparatus was placed in operation in August, 1944. More than 700 specimens have been tested in the two devices embodying numerous variables of aggregate, cement, air-entraining admixture, and water-cement ratio.

The apparatus has been found to operate satisfactorily and gives good results. The method is believed to be preferable to other available tests, such as the accelerated soundness tests of aggregate, because it permits materials for concrete to be tested in concrete. This is important, because there is evidence that some materials behave quite differently when tested in an unconfined condition than they do when confined in concrete. The apparatus is relatively costly, the large unit costing about 10,000 dollars, and the small unit about 3,000 dollars, but the results obtained are believed to be of greater value than those obtained by testing cylinders in a compression testing machine costing 10,000 dollars.

Lowering Crane Loads.

IN discussing a case in which a man was injured because he passed under a crane load as it was being lowered, the Royal Society for the Prevention of Accidents states in its Bulletin that, in the opinion of the Society, the prime responsibility for avoiding the lowering of crane loads on to persons in the vicinity of a crane must rest with the operator. If he has not a clear view then a signaller should be employed; in places subject to the Docks Regulations, 1934, a signaller is compulsory unless the crane driver has an unrestricted view or the Chief Inspector grants a certificate of exemption. Even when the employment of a signaller is not obligatory or strictly necessary, the presence of one is a great help, as he can warn persons who approach the danger zone without needing to shout at them over any great distance. The main objection to an audible warning signal, such as a bell or klaxon, is that the crane driver might tend to rely on it to clear the way for a load instead of exercising full care in hoisting and lowering. If an audible warning bell is provided its use should be limited to emergencies in which the stopping of the crane is not enough to avert an accident. In brief, the responsibility for raising and lowering crane loads without endangering other people must always rest with those in charge of the load—either the crane driver or his signaller as circumstances dictate.

Fuel Consumption of Lepol Kilns.

AFTER four years continuous operation it has been found that the fuel consumption of two Lepol kilns installed at a cement works in California is less than 133,000 B.Th.U. per ton compared with 208,000 B.Th.U. per ton in the case of other kilns at the same works. The kilns are 106 ft. long by 11 ft. inside diameter, and use oil fuel

In the operation of the Lepol kiln the dry raw materials are nodulised (*Fig.* 1), and preheated so that hot gases from the back ends of comparatively short rotary

Fig. 1.—Interior of Noduliser.

kilns may be forced through a bed of raw material being fed, so as to pre-heat and partially calcine the raw materials at the point of feed into the kilns. An installation consists of a noduliser elevated over and beyond the back end of the kiln and an enclosed grate moving at the rate of 29 in. per minute, carrying nodules of raw material to the kiln while the hot kiln-exit gases are drawn through a uniform bed of nodules on the grate. Thus the exhaust kiln gas is utilised in pre-heating the feed. There are heat-recovery apparatus at the back ends of the kilns and air-quenching clinker coolers at the point of clinker discharge, with pre-heating of the secondary air for combustion. The kilns ride on two sets of

rollers and slope at $\frac{7}{16}$ in. to 1 ft.; they rotate a little slower than one revolution per minute.

Accessory handling equipment consists of two 7 in. Fuller-Kinyon pumps which place the blended raw materials into eight 15 ft. by 55 ft. feed tanks, four for each kiln, and pneumatic conveyors beneath the tanks which feed to the pumps. The pneumatic conveyors are close-circuited with separate dust collectors.

The noduliser is a cylindrical drum measuring 8 ft. 10 in. by 18 ft., and nodulisation consists of agitating, or tumbling, continuously the raw materials in the presence of a controlled amount of water. Water enters the drum from an overhead constant-level tank as a spray through a horizontal pipe with a number of perforations, while the side of the drum is constantly cleaned by power-driven blades. The nodules are fed to the moving cast-iron grate, measuring 12 ft. 5 in. in width and 47 ft. 6 in. in length, which conveys a uniform bed of material, about 6 in. or 7 in. thick, to the feed end of the kiln. The entire back end including the kiln connection and grate is enclosed with steel plates, brick lined. Any material dropping over the sides of the moving grate is conveyed by a drag conveyor to the noduliser. The induced-draught fan is at floor level, and is driven by a 125-h.p. motor at 870 r.p.m. Hot exit gases from the kiln enter over the top of the moving grate, are drawn through the nodules on the grate, and exhausted by the fan through the kiln stack.

The fineness of grind of the raw materials has a direct bearing upon the efficiency of operation since the degree of fineness influences nodulisation and nodule size determines the degree of heat interchange from the kiln gases to the raw materials. Raw materials consist of limestone and shale. After preliminary crushing and blending the raw material is pulverised to kiln feed fineness through ball mills in closed circuit. The standard fineness is approximately 90 per cent. through a 200-mesh sieve. Too fine grinding makes nodulisation to the desired sizes difficult, experience being that the nodules would be too small and too uniform in shape. The ideal is a mixture of sizes that will effect a rapid transfer of kiln gases through the bed on the grate and yet offer sufficient resistance to the passage of gases for an effective take-up of heat by the nodules. The nodules contain approximately 12 to 14 per cent. of water when discharged upon the grate and emerge from the discharge end of the kiln as clinker in approximately the same size and range of sizes except for little agglomeration.

The kilns are fired by fuel oil at an indicated temperature of 2,800 to 2,900 deg. F. The flame is short and intense. Temperatures are taken at six points within the kiln and grate housing, and draught readings are taken at five positions. The pressure drop is much higher than that through other kiln systems by virtue of drawing the kiln-exit gases through a bed of material. The drop in pressure through the kiln is 0·08 in., the reading on which draught control is based. The pressure drop through the grate is approximately 0·80 in., and the exhaust fan is set for a reading of about 6 in. draught. Temperatures from 1,600 deg. F. to 2,000 deg. F. prevail at various points over the forepart of the grate. Temperatures

do not exceed 800 deg. F. at the point of contact of the nodules with the grate, and 400 to 500 deg. F. adjacent to the grate sprocket. The top of the nodule bed is at red heat when discharged into the kiln, while the lower level of the stream is thoroughly dried but not at calcination temperature. Stack temperatures range from 260 deg. F. to 300 deg. F.

In comparison with the standard kilns in the plant, which have no coolers, heat recuperation or dust collection, the Lepol kilns require 360 lb. less raw material per ton of clinker, and the clinker as produced with the same material has a higher C_3S content. With a nodulised feed the dust losses are much lower than with the normal finely ground material. The lining consists of 70 per cent. alumina blocks for the first 10 ft., followed by 21 ft. of magnesite blocks in the hot zone, 70 per cent. alumina back to the 70 ft. point, and then 60 per cent. alumina blocks to the end of the kiln.

Determination of Sodium, Potassium and Lithium in Portland Cement.

IN a paper by Mr. Arnim W. Hetz published in the Journal of the U.S. National Bureau of Standards for February, 1945 (Research Paper No. 1633), spectrographic methods, which are quicker than chemical methods, are described for the determination of sodium, potassium, and lithium in Portland cement. For the determination of sodium and potassium the sample is mixed with a mineral base containing silver for the internal standard. For lithium a standard mixture of graphite and strontium carbonate is added to the cement sample. In either case a fixed amount of the resultant mixture is placed in the crater of a graphite electrode, which is made the lower positive element of a direct-current arc. The Na 8194.81 A, *K* 7698.98 A, and Li 3232.61 A lines are used for the quantitative calculations. A discussion of the development of the method is given, followed by details of the adopted analytical procedure. The spectrographic analyses of 41 cements for sodium and potassium are given for comparison with the chemical values.

Spectrographic analysis depends upon the fact that elements of a substance can be made to radiate light, a spectrum of which has many lines characteristic of the elements in the source. The relative intensities of these lines for different elements bear a definite relation to the relative quantities, kind, and number of elements in the source, but with the present state of knowledge of spectroscopy this relation is too complicated to predict. It has been found that by controlling the excitation used for the source and dividing analytical problems into type cases, empirical data may be obtained that will give a rapid analytical method. This method of analysis is ideally suited to problems in which (1) a rapid determination is required, (2) the size of the sample is necessarily small, (3) the concentrations of the elements in question are small, or (4) the chemical method is difficult or uncertain. Many examples may be found in the literature on the

subject where the accuracy of the results is as good as that of the best chemical methods, and the time for the analysis is a matter of minutes for the spectrographic method compared with hours for the chemical method. The percentage error of spectrographic analysis tends to remain constant regardless of the concentration, whereas in chemical analysis the absolute error tends to be constant. Thus, for high concentration, chemical methods are preferable to spectrographic methods, whereas for low concentrations the reverse is true. In general, spectrographic analysis has proved advantageous for the determination of concentrations of elements below about 5 per cent.

The interest in spectrographic methods by the cement industry arises from the presence in Portland cement of small quantities of metallic elements, the effects of which it is important to study. Of particular significance are the alkali elements, which are under critical observation by various laboratories in connection with questions on the durability of concrete. The spectrographic method does not require the difficult separations that are involved in the chemical determinations of the alkali elements, and the advantage of speed will be even greater if the method is extended to include other minor elements such as magnesium, manganese, and titanium.

No general method of spectrographic analysis has proved entirely satisfactory. It is necessary to make a study of the type of substance to be analysed, because the intensities of the lines of the minor elements depend not only on their concentrations but also in various degrees upon the major elements and the physical and chemical states of all the elements present. Portland cement, with its limited variability of the major components, may be treated as a single type of material for spectrographic analysis. Primary considerations for this application are the preparation of the sample and excitation of the spectrum. Subsequent details of spectroscopy and photography are readily decided according to established principles.

The procedure described in the paper was designed to minimise and control self-reversal, unequal rate of evaporation of the alkali and reference elements, unequal distribution in the arc of intensity of the spectrum of the alkali and reference elements, and the effect of extraneous elements.

An estimate of the reproducibility of the sodium and potassium determinations in terms of the probable error for the average of duplicate determinations is 4 per cent. of the Na_2O concentration and 5·8 per cent. of the K_2O concentration. The accuracy of the method cannot be expressed in such simple figures but is illustrated by a comparison of chemical and spectrographic analyses of 41 Portland cements where the spectrographic results were found to differ from the chemical results by an average value of 0·06 per cent. Chemical results obtained in five different laboratories are given in this comparison.

The spectrographic examinations of 30 Portland cements for lithium indicated that in no case was Li_2O present in amounts in excess of 0·05 per cent. The method was checked by the analysis of several cements to which spodumene of known LiO_2 content had been added